EXPERIMENTAL FACILITY FOR PROGRESSIVE EDGE WAVES

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1. Introduction

Edge waves are one type of wave phenomena that may be an especially important factor for understanding coastal hydrodynamics. These waves are one of a class of trapped wave phenomena which can occur nearshore by wave refraction owing to the variable water depth. Edge waves propagate parallel to the shoreline with their crests pointing offshore while their amplitude is maximum at the shore and decays asymptotically to zero in the offshore direction. Thus, energy of edge waves is concentrated and confined to the near-shore region. Because edge-wave motions are boundary dominated flows, they appear to be influenced by the fluid viscosity and to deviate from the prediction of the inviscid theory (Yeh, 1985;1986;1987).

The experimental wave basin was designed specifically for the investigation of the fundamental mechanics of progressive edge waves in a real fluid environment. The primary objective of the study is to measure detailed flow fields created by 'clean' edge waves; the measurements include that in the bottom boundary layer and flow interactions within the swash zone, i.e. near the air-water-beach contact line. Because of the nature of the study, the basin was constructed with extremely high precision.

2. Edge-Wave Basin

A view of the edge-wave basin and the schematic drawings are shown in Figs. 1 and 2, respectively. The dimensions of the basin are 13.4 m long, 5.5 m wide, and 0.9 m deep. The entire tank is elevated so that the bottom floor of the tank is located 1.1 m from the laboratory floor. This setup together with the glass beach (described below) enable us to measure a velocity field from below using the laser-doppler anemometer (LDA) as well as various techniques of flow visualization.

The steel frame structure having the height adjustable column members was designed and erected with the aid of a visible laser level instrument so as to level the basin floor to within 1.6 mm of tolerance from the horizontal plane for the fully loaded condition. The tank floor and de walls were constructed with 2.86 cm thick sheets of "oriented stranded boards", bolted down to the steel frame, and then lined with fiberglass laminate. Five layers of chopped strand fiberglass mat were used to achieve the stiff and water-tight surface of the tank. The finished floor is very close to the horizontal (± 1.6 mm tolerai). Considering the size of the tank, this precision of the tank i more than satisfactory. In

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order to achieve the precision of the beach construction, the region of the toe of the glass beach section was made absolutely horizontal by pouring resin; the liquid resin formed the smooth horizontal plane by gravity.

The central section of the beach is constructed of a 2.4 m long, 3 m wide, and 1.27 cm thick tempered glass plate. As shown in Fig. 2, the glass plate has a water tight seal to provide the dry observation section. Outside of the observation section (the glass beach section), the beach modules are constructed with 1.27 cm thick Extren sheets supported by the Extren frame. Extren is a proprietary combination of fiberglass reinforcements and thermosetting polyester system; it is relatively stiff, resistant against corrosion, and is hydrophilic (wettable). The wettability of the beach material is crucial to the edge-wave experiments in order to minimize the effects of the air-water-beach contact line. This consideration is important since the maximum energy of an edge wave is located at the shoreline.

The slope of the beach, β, is set 15° from the horizontal. With this slope, which can be considered to be mild, $\beta << O(1)$, edge waves of Stokes' mode ($n = 0$) and two other higher modes ($n = 1$, and 2) are possible (Ursell, 1952). For a milder slope, other higher modes are possible and the separation of the modes from the measured raw data would become difficult. In addition, it is also advantageous that the slope $\beta = 15°$ is an angle of the form $\beta = \pi/2m$, m = integer (in this case $m = 6$), for which the explicit analytical solution for the leaky mode is available. (For the slope $\beta \neq \pi/2m$, no explicit solution based on the full water-wave theory has been found.)

Edge waves are generated directly at one end of the beach by the wave paddle as shown in Fig. 2. The overall wave-generating system consists of three components: the wave paddle, the hydraulic power unit, and the electrical servo system. The hydraulic power unit drives the wave paddle, while the electrical servo system controls the paddle motion. A wedge-shaped wave paddle is hinged offshore and oscillated in the longshore direction about the axis perpendicular to the beach surface. Note that this linear approximation of the paddle motion for edge waves with exponential offshore decay is analogous to that of a "plunger" or "flap" type wavemaker used for the generation of deep-water waves. (As discussed in Yeh (1987), the characteristics of edge waves are analogous to that of two-dimensional deep-water waves.) Furthermore, a uniform paddle velocity with respect to a line perpendicular to the beach surface coincides with the theoretical velocity field of linear edge waves. With the exception of the wave paddle, the entire wave-generating system is installed directly on the laboratory floor outside the tank; thus the mechanical vibration associated with the system does not disturb the water in the tank. Even the wave paddle itself is supported by the structure outside the tank so that any unwanted vibration caused by the paddle motion does not transmit to the beach surface, the tank walls or floor.

The top of the side walls is made of steel tubing which can support an instrument carriage that can traverse along the tank. There are two drains in the tank as shown in Fig. 2; one is used simply to drain the water from the tank or to recirculate the water through the filtering system The other drain outlet is placed at 71 cm above the tank floor in order to skim the water surface to avoid excessive surface contamination of the water.

The flow field in the tank can be measured directly through the glass-plate beach with an optics device, e.g. the backscattering LDA. I believe that this arrangement is the only way to accurately measure the velocity field with the LDA since a focal point of the laser beams can be sufficiently short and the refraction effects can be minimized. In addition, because of the large and dry working area underneath the glass beach, this setup has an advantage for traversing readily the LDA measuring points as well as for flow visualization. Note that the LDA cannot be used from above because of the variable refraction caused by the air-

water interface curvature created by the wave motion, and a conventional intrusive flow meter (e.g. an electro-magnetic flow meter) is inadequate because velocity measurements are required in water of very shallow depth.

It is emphasized that the tank is constructed with extremely high precision in spite of its relatively large size. A wave tank of this size is essential to generate clean and measurable edge waves. Scaled down waves generated in a smaller size tank would cause many adverse effects; e.g. 1) excessively strong viscous effects, 2) unwanted disturbances such as leaky-mode waves which might be reflected back from the side walls, and 3) inaccurate measurements of the wave field because edge waves decay exponentially offshore. A weakly nonlinear edge wave, say ak = 0.2, of the Stokes mode having the wave length 2 m on the beach $\beta = 15°$ has the wave amplitude of 3.6 mm at 50 cm offshore, i.e. the fundamental investigation of edge waves requires measurements of small scale motions in a large fluid domain. Moreover, one of the primary objectives is to explore the fluid mechanics associated with the flow near the air-water-beach contact line, including the boundary layer formation and its interaction with the free surface, and the surface tension effects due to the contact line. Such experiments require measurements in the spatial resolution of the order of millimeters.

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Figure 1. A view of edge-wave basin.

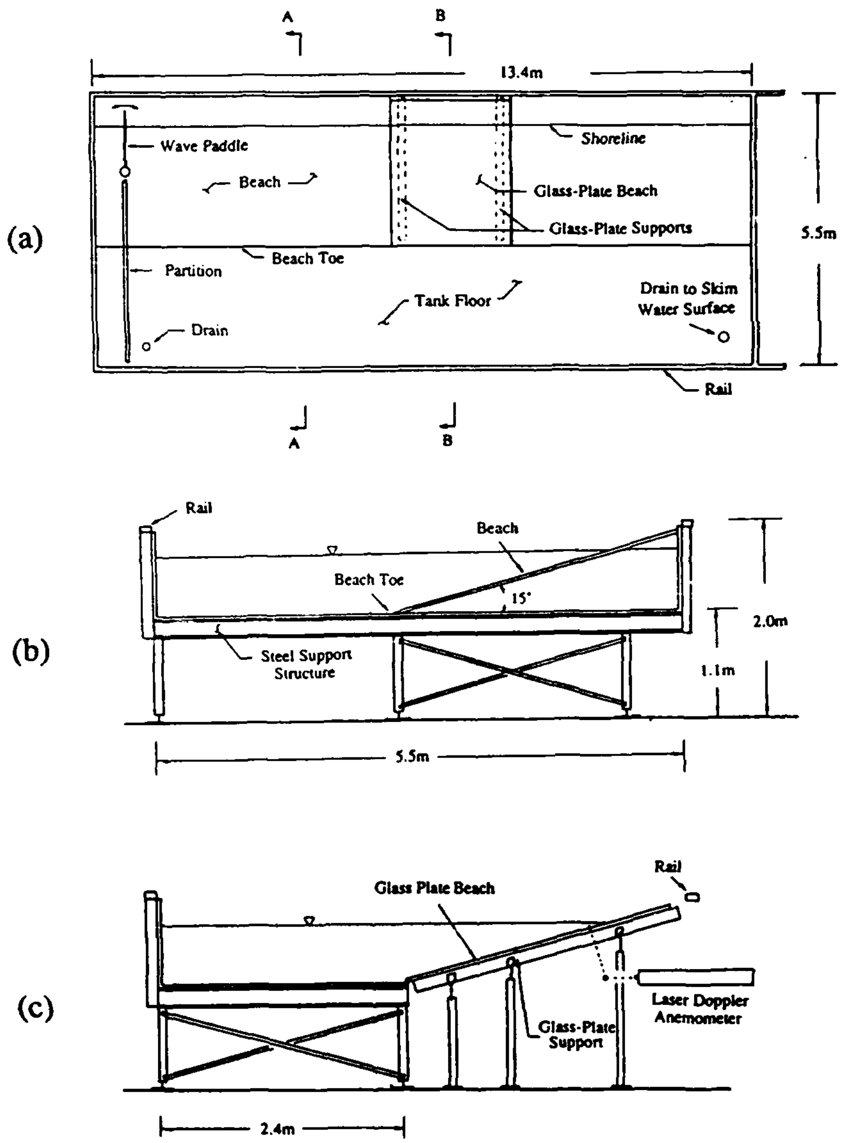

Figure 2. Schematic drawings of edge-wave basin. a) plan view; b) elevation view, Section A-A; c) Section B-B.